Art. 34 Amendment

10/567514

IAP20 Rec'd PCT/PTO 07 FEB 2006

手続補正書

（法第１１条の規定による補正）

PCT
27.10.05
受領印

特許庁長官　殿

１．国際出願の表示　　ＰＣＴ／ＪＰ２００４／０１１５６８

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４．補正の対象　　請求の範囲

５．補正の内容　　別紙の通り

・請求項２については、「請求項７又は９又は１１」を「請求項７」に補正した。

・請求項３、請求項４については、請求項４の内容を請求項３に入れる。これより、請求項４を削除する。

・請求項８については、「K_k、$\hat{\Sigma}_{k+1|k}^{1/2}$ 」を「$\hat{\Sigma}_{k+1|k}^{1/2}$」に、「式（２１）と（２２）を用いて」を「式（２１）を用いて」に補正した。

・請求項８については、$\hat{\Sigma}_{k|k-1}$ とC_kの両方の初期条件であるのでそのように明記した。また、「初期条件及びゲイン行列 K_k に基づき、」を「初期条件のもとで、」に補正した。

・請求項１０については、明確になるよう「初期条件及びゲイン行列 K^{-}_{k} に基づき、」を「初期条件のもとで、」に補正した。

・請求項１４については、u_{k-i} を$u(k-i)$に補正した。

６．添付書類の目録

（１）請求の範囲　第２８、２９、３０、３１、３１／１、３１／２、３２、３３、３３／１、３４、３４／１、３４／２、３５、３６、３６／１、３６／２、３７、３８、３８／１、３９、４０、４０／１　頁

10/567514

CLAIMS IAP20 Rec'd PCT/PTO 07 FEB 2006

1. (Canceled)

2. (Amended) The system estimation method according to claim 7 ~~or 9 or 11~~, wherein the processing section calculates the existence condition in accordance with a following expression:

$$\hat{\Sigma}_{i|i}^{-1} = \hat{\Sigma}_{i|i-1}^{-1} + \frac{1-\gamma_f^{-2}}{\rho} H_i^T H_i > 0, \quad i = 0, \ldots, k \tag{17}$$

3. (Amended) The system estimation method according to claim 7 or 9 or 11, wherein the processing section calculates the existence condition in accordance with a following expression:

$$-\varrho\hat{\Xi}_i + \rho\gamma_f^2 > 0, \quad i = 0, \cdots, k \tag{18}$$

here,

$$\varrho = 1-\gamma_f^2, \quad \hat{\Xi}_i = \frac{\rho H_i K_{s,i}}{1 - H_i K_{s,i}}, \quad \rho = 1-\chi(\gamma_f) \tag{19}$$

where the forgetting factor ρ and the upper limit value γ_f have a following relation:

$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotonically damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.

4. (Canceled)

~~(Amended) The system estimation method according to claim 7 or 9 or 11, wherein the forgetting coefficient ρ and the upper limit value~~ $\cancel{\gamma_f}$ ~~have a following relation:~~

~~$0 < \rho = 1 - \chi(\gamma_f) \leq 1$, where $\chi(\gamma_f)$ denotes a monotone damping function of γ_f to satisfy $\chi(1) = 1$ and $\chi(\infty) = 0$.~~

5. (Canceled)

6. (Canceled)

7. ~~(Amended)~~ A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing

section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions (20) to (22), or, expression (20) and expressions which are deleted J_1^{-1} and J_1 in the expressions (21) and (22),:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{20}$$

$$K_{s,k} = K_k(:,1)/R_{e,k}(1,1) \ , \ K_k = \rho^{\frac{1}{2}}(\rho^{-\frac{1}{2}}K_k R_{e,k}^{-\frac{1}{2}} J_1^{-1}) J_1 R_{e,k}^{\frac{1}{2}} \tag{21}$$

$$\left[\begin{array}{c|c} R_k^{\frac{1}{2}} & C_k\hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \\ \hline 0 & \rho^{-\frac{1}{2}}\hat{\Sigma}_{k|k-1}^{\frac{1}{2}} \end{array}\right]\Theta(k) = \left[\begin{array}{c|c} R_{e,k}^{\frac{1}{2}} & 0 \\ \hline \rho^{-\frac{1}{2}}K_k R_{e,k}^{-\frac{1}{2}} J_1^{-1} & \hat{\Sigma}_{k+1|k}^{\frac{1}{2}} \end{array}\right] \tag{22}$$

Where,

$$R_k = R_k^{\frac{1}{2}} J_1 R_k^{\frac{T}{2}},\ R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}}\gamma_f \end{bmatrix},\ J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix},\ \hat{\Sigma}_{k|k-1} = \hat{\Sigma}_{k|k-1}^{\frac{1}{2}}\hat{\Sigma}_{k|k-1}^{\frac{T}{2}}$$

$$R_{e,k} = R_k + C_k\hat{\Sigma}_{k|k-1}C_k^T,\ C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix},\ R_{e,k} = R_{e,k}^{\frac{1}{2}} J_1 R_{e,k}^{\frac{T}{2}},\ \hat{x}_{0|0} = \check{x}_0 \tag{23}$$

$\Theta(k)$ denotes a J-unitary matrix, that is, satisfies $\Theta(k)J\Theta H(k)^T = J$, $J = (J_1 \oplus I)$, I denotes a unit matrix, $K_k(:,1)$ denotes a column vector of a first column of the matrix K_k,

here,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

y_k: the observation signal,

F_k: the dynamics of the system,

$K_{s,k}$: the filter gain,

H_k: the observation matrix,

$\hat{\Sigma}_{k|k}$: corresponding to a covariance matrix of an error of $\hat{x}_{k|k}$,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence

condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

8. (Amended) The system estimation method according to claim 7, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates ~~K_k and~~ $\hat{\Sigma}_{k+1|k}^{1/2}$ by using the expression (22);

a step at which the processing section calculates the filter gain $K_{s,k}$ based on an initial condition of $\hat{\Sigma}_{k|k-1}$ and an initial condition of C_k~~, and the matrix gain k_k~~ by using the expression~~s~~ (21) ~~and (22)~~;

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (20); and

a step at which the processing section repeatedly executes the step of calculating by using the expression (22~~20~~), the step of calculating by using the expressions (21)~~ and (22)~~, and, the step of updating while advancing the time k.

9. ~~(Amended)~~ A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix K_k and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \tag{61}$$

$$K_{s,k} = K_k(:,1)/R_{e,k}(1,1)\ ,\ K_k = \rho^{\frac{1}{2}}(\overline{K}_k R_{e,k}^{-\frac{1}{2}}) R_{e,k}^{\frac{1}{2}} \tag{62}$$

$$\begin{bmatrix} R^{\frac{1}{2}}_{e,k+1} & 0 \\ \begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} R^{-\frac{T}{2}}_{e,k+1} J_1 & \tilde{L}_{k+1} R^{-\frac{T}{2}}_{r,k+1} \end{bmatrix} = \begin{bmatrix} R^{\frac{1}{2}}_{e,k} & \check{C}_{k+1} \tilde{L}_k R^{-\frac{1}{2}}_{r,k} \\ \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R^{-\frac{1}{2}}_{e,k} J_1 & \rho^{-\frac{1}{2}} \tilde{L}_k R^{-\frac{1}{2}}_{r,k} \end{bmatrix} \Theta(k) \tag{63}$$

here, $\Theta(k)$ denotes an arbitrary J-unitary matrix, and $C_k = C_{k+1}\Psi$ is established. where

$$R_k = R_k^{\frac{1}{2}} J_1 R_k^{\frac{T}{2}},\ \ R_k^{\frac{1}{2}} = \begin{bmatrix} \rho^{\frac{1}{2}} & 0 \\ 0 & \rho^{\frac{1}{2}}\gamma_f \end{bmatrix},\ \ J_1 = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix},\ \ \hat{\Sigma}_{k|k-1} = \hat{\Sigma}^{\frac{1}{2}}_{k|k-1} \hat{\Sigma}^{\frac{T}{2}}_{k|k-1}$$

$$R_{e,k} = R_k + C_k \hat{\Sigma}_{k|k-1} C_k^T,\ \ C_k = \begin{bmatrix} H_k \\ H_k \end{bmatrix},\ \ R_{e,k} = R^{\frac{1}{2}}_{e,k} J_1 R^{\frac{T}{2}}_{e,k},\ \ \hat{x}_{0|0} = \check{x}_0 \tag{23}$$

here,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

y_k: the observation signal,

$K_{s,k}$: the filter gain,

H_k: the observation matrix,

$\Theta(k)$: the J-unitary matrix, and

$R_{e,k}$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

10. (Amended) The system estimation method according to claim 9, wherein the step of executing the hyper H_∞ filter includes:

a step at which the processing section calculates $\check{K}_k$ based on an initial condition of $R_{e,k+1}$, $R_{r,k+1}$ and $\check{L}_{k+1}$~~, and the matrix gain~~ ~~$\check{K}_k$~~ by using the expression (63);

a step at which the processing section calculates the filter gain $K_{s,k}$ based on the initial condition and by using the expression (62);

a step at which the processing section updates a filter equation of the H_∞ filter of the expression (61); and

a step at which the processing section repeatedly executes the step of calculating by using the expression~~s (62) and~~ (63), the step of calculating by using the expression (62~~61~~), and, the step of updating while advancing the time k.

11. ~~(Amended)~~ A system estimation method for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a

term corresponding to a previously given upper limit value γ_f, and the system estimation method comprises:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix $\bar{K}_k$ and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{25}$$

$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{27}$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{28}$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{29}$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T\check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{30}$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix},\quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k],\quad \check{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T,\quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix},\quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\},\quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2},\quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix},\quad \overline{K}_0 = 0,\quad \hat{x}_{0|0} = \check{x}_0,\quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \tag{31}$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $\check{K}_k$, and

$R_{e,k}$, $\tilde{L}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

12. (Canceled)

13. ~~(Amended)~~ The system estimation method according to claim 7 or 9 or 11, wherein an estimated value $\check{z}_{k|k}$ of the output signal is obtained from the state estimated value $\hat{x}_{k|k}$ at the time k by a following expression:

$\check{z}_{k|k} = H_k\hat{x}_{k|k}$.

14. (Amended) The system estimation method according to claim 7 or 9 or 11, wherein the H_∞ filter equation is applied to obtain the state estimated value $\hat{x}_{k|k}=[\hat{h}_1[k],\cdots, \hat{h}_N[k]]^T$

a pseudo-echo is estimated by a following expression:

$$\hat{d}_k = \sum_{i=0}^{N-1} \hat{h}_i[k] u_{(k-i)}, \quad k = 0, 1, 2, \cdots \qquad (34)$$

and

an echo canceller is realized by canceling an actual echo by the obtained pseudo-echo.

15. ~~(Amended)~~ A system estimation program for causing a computer to make state estimation robust and to optimize a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a

value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix $\overline{K}_k$ and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \tag{25}$$

$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{27}$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{28}$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \tag{29}$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T\check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \tag{30}$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix},\ \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k],\ \check{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T,\ R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix},\ \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\},\ \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2},\ R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix},\ \overline{K}_0 = 0,\ \hat{x}_{0|0} = \check{x}_0,\ \overline{K}_k = \rho^{-\frac{1}{2}}K_k \tag{31}$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the

observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $K^{\sim}_k$, and

$R_{e,k}$, $L^{\sim}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

16. ~~(Amended)~~ A computer readable recording medium recording a system estimation program for causing a computer to make state estimation robust and to optimize a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain

which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the computer readable recording medium recording the system estimation program causes the computer to execute:

a step at which a processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from a storage section or an input section;

a step at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a step of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix $K^{\check{}}_k$ and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k \hat{x}_{k-1|k-1}) \tag{25}$$

$$K_{s,k} = \rho^{\frac{1}{2}} \overline{K}_k(:,1)/R_{e,k}(1,1) \tag{26}$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \tag{27}$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}} \tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \tag{28}$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1} \tilde{L}_k R_{r,k}^{-1} \tilde{L}_k^T \check{C}_{k+1}^T \tag{29}$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T \check{C}_{k+1}^T R_{e,k}^{-1} \check{C}_{k+1} \tilde{L}_k \tag{30}$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k], \quad \check{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1 \check{\Sigma}_{1|0} \check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \overline{K}_0 = 0, \quad \hat{x}_{0|0} = \check{x}_0, \quad \overline{K}_k = \rho^{-\frac{1}{2}} K_k \tag{31}$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $\overline{K}_k$, and

$R_{e,k}$, $\tilde{L}_k$: an auxiliary variable.

a step at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a step at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a step at which the processing section sets the upper limit

value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the step of executing the hyper H_∞ filter.

17. ~~(Amended)~~ A system estimation device for making state estimation robust and optimizing a forgetting factor ρ simultaneously in an estimation algorithm, in which

for a state space model expressed by following expressions:

$x_{k+1} = F_k x_k + G_k w_k$

$y_k = H_k x_k + v_k$

$z_k = H_k x_k$

here,

x_k: a state vector or simply a state,

w_k: a system noise,

v_k: an observation noise,

y_k: an observation signal,

z_k: an output signal,

F_k: dynamics of a system, and

G_k: a drive matrix,

as an evaluation criterion, a maximum value of an energy gain which indicates a ratio of a filter error to a disturbance including the system noise w_k and the observation noise v_k and is weighted with the forgetting factor ρ is suppressed to be smaller than a term corresponding to a previously given upper limit value γ_f, and

the system estimation device comprises:

a processing section to execute the estimation algorithm; and

a storage section to which reading and/or writing is performed by the processing section and which stores respective observed values, set values, and estimated values relevant to the state space model, wherein,

a means at which the processing section inputs the upper limit value γ_f, the observation signal y_k as an input of a filter and a value including an observation matrix H_k from the storage section or an input section;

a means at which the processing section determines the forgetting factor ρ relevant to the state space model in accordance with the upper limit value γ_f;

a means of executing a hyper H_∞ filter at which the processing section reads out an initial value or a value including the observation matrix H_k at a time from the storage section and obtains a filter gain $K_{s,k}$ by using the forgetting factor ρ and a gain matrix $\bar{K}_k$ and by following expressions:

$$\hat{x}_{k|k} = \hat{x}_{k-1|k-1} + K_{s,k}(y_k - H_k\hat{x}_{k-1|k-1}) \qquad (25)$$

$$K_{s,k} = \rho^{\frac{1}{2}}\overline{K}_k(:,1)/R_{e,k}(1,1) \qquad (26)$$

$$\begin{bmatrix} \overline{K}_{k+1} \\ 0 \end{bmatrix} = \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} - \rho^{-\frac{1}{2}}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \qquad (27)$$

$$\tilde{L}_{k+1} = \rho^{-\frac{1}{2}}\tilde{L}_k - \begin{bmatrix} 0 \\ \overline{K}_k \end{bmatrix} R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \qquad (28)$$

$$R_{e,k+1} = R_{e,k} - \check{C}_{k+1}\tilde{L}_k R_{r,k}^{-1}\tilde{L}_k^T\check{C}_{k+1}^T \qquad (29)$$

$$R_{r,k+1} = R_{r,k} - \tilde{L}_k^T\check{C}_{k+1}^T R_{e,k}^{-1}\check{C}_{k+1}\tilde{L}_k \qquad (30)$$

Where,

$$\check{C}_{k+1} = \begin{bmatrix} \check{H}_{k+1} \\ \check{H}_{k+1} \end{bmatrix}, \quad \check{H}_{k+1} = [u_{k+1}\ u(k+1-N)] = [u(k+1)\ u_k], \quad \check{H}_1 = [u(1), 0, \ldots, 0]$$

$$R_{e,1} = R_1 + \check{C}_1\check{\Sigma}_{1|0}\check{C}_1^T, \quad R_1 = \begin{bmatrix} \rho & 0 \\ 0 & -\rho\gamma_f^2 \end{bmatrix}, \quad \check{\Sigma}_{1|0} = \mathrm{diag}\{\rho^2, \rho^3, \ldots, \rho^{N+2}\}, \quad \rho = 1 - \chi(\gamma_f)$$

$$\tilde{L}_0 = \begin{bmatrix} 1 & 0 \\ 0 & 0 \\ 0 & 1 \end{bmatrix} \in \mathcal{R}^{(N+1)\times 2}, \quad R_{r,0} = \begin{bmatrix} -1 & 0 \\ 0 & \rho^{-N} \end{bmatrix}, \quad \overline{K}_0 = 0, \quad \hat{x}_{0|0} = \check{x}_0, \quad \overline{K}_k = \rho^{-\frac{1}{2}}K_k \qquad (31)$$

here,

y_k: the observation signal,

F_k: the dynamics of the system,

H_k: the observation matrix,

$\hat{x}_{k|k}$: the estimated value of the state x_k at the time k using the observation signals y_0 to y_k,

$K_{s,k}$: the filter gain, obtained from the gain matrix $\check{K}_k$, and

$R_{e,k}$, $\tilde{L}_k$: an auxiliary variable.

a means at which the processing section stores an estimated value of the state x_k by the hyper H_∞ filter into the storage section;

a means at which the processing section calculates an existence condition based on the upper limit value γ_f and the forgetting factor ρ by the obtained observation matrix H_i or the observation matrix H_i and the filter gain $K_{s,i}$, and

a means at which the processing section sets the upper limit value to be small within a range where the existence condition is satisfied at each time and stores the value into the storage section, by decreasing the upper limit value γ_f and repeating the means of executing the hyper H_∞ filter.